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THE MODE OF GROWTH OF THE RADIATES.

BY A. S. PACKARD, JR.

III. THE ACTINOZOA.

The sea anemones and coral polypes are more highly developed than the Hydroids, since the mouth opens into a double digestive cavity, which is supported for its whole length by the six primary curtains or septa. The second and lower half of the cavity enlarges greatly, and communicates with the general cavity of the body, the upper portion being entire, tubular, and forming a sort of throat opening into the proper digestive cavity. In the Hydroids, the digestive cavity, it may be remembered, is simply hollowed out of the body cavity and is a more primitive affair than that of the Actiniæ.

While in the Hydroids also the ovaries hang outside the body cavity, in the true polypes they are attached to the septa or walls of the radiating chambers, so that the eggs, when ripe, drop down into the body cavity, whence they pass out through the mouth, or, as observed by Lacaze-Duthiers, in the coral polypes through the tentacles. The chambers between the septa correspond to the water canals, or chymiferous tubes of the Hydroids.

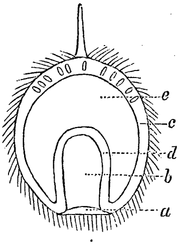
In the coral polypes the coral is secreted in the chambers, so that there are soft partitions alternating with the limestone ones. The tentacles which surround the mouth vary greatly in number. They are hollow, each communicating with a chamber.

The polypes are divided into (1), the Actinoids (Zoantharia) which either secrete no limestone, as in the sea anemones, or form a coral stock, as in the coral polypes, and have an indefinite number of tentacles, and (2), the Halcyonoids, in which the tentacles are eight in number. Such are the sea fans (Gorgonia) and Halcyonium, which does not secrete a coral stock.

Development. The life history of a polype is soon told. Naturalists are indebted to the magnificent memoirs of Lacaze-Duthiers for a full biography of not only several genera of sea anemones (*Actinia mesembryanthemum*, Bunodes and Sagartia) but also of the Gorgonia, Halcyonium, red coral, and the Astræoides, a Mediterranean form allied to Astræa.

The young sea anemone develops without any metamorphosis, directly into the adult condition. Lacaze-Duthiers could not determine by actual sight how fecundation of the egg takes place, or whether the egg passes through a morula stage or not, though he infers, with every reason, that this stage, *i. e.*, the segmentation of the egg contents, takes place in the ovary. The ovaries and spermaries are in the Actiniæ situated in the same individual; the eggs are oval, while the spermatic cells are of the usual tailed form. The fecundated egg in the state in which it was first seen by Lacaze-Duthiers was oval, and surrounded by a dense coat of transparent conical spinules. He was soon able to detect the presence of the two primitive germinal layers, the ectoderm and endoderm. Fig. 75 (from Metschnikoff) illustrates the relation of the embryonal layers in the larva of another polype which he calls "kaliphobenartige Polypen larve;" *a*, primitive opening into the gastro-vascular cavity; *b*, *c*, ectoderm; *d*, entoderm; *e*, body cavity), showing that the walls of the digestive cavity are formed by the entoderm; and Metschnikoff's figure shows that the embryo polype has a greater resemblance to the embryo starfish of the same age than the acalephs.

Fig. 75.



Ciliated larva of a Polype.

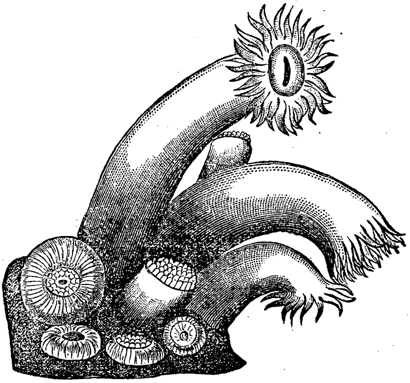
Two lobes next appear within the body, these subdivide into four, eight and finally twelve primitive lobes. This stage is represented by the corresponding stage of the coral (Fig. 77, B). Not until after the twelve primitive lobes are fully formed do the tentacles begin to make their appearance. When the first twelve tentacles have grown out, twenty-four more arise, and so on, until with its increasing size the actinia is provided with the full number peculiar to each species. The preceding remarks apply to *Actinia mesembryanthemum*, but Lacaze-Duthiers observed the same changes in two species of Sagartia and in *Bunodes gemmacea.*

Turning now to the stony corals we will give more fully the sequence of events in the life of a coral builder of the Mediterranean, the *Astrœoïdes calycularis*, so faithfully narrated by Lacaze-Duthiers. Fig. 76 taken from Tenney's "Manual of Zoology" illustrates this coral in various stages of expansion.

He studied this coral on the coast of Algiers, and found that reproduction took place between the end of May and July, the young developing most actively at the end of June. Unlike Actinia, which is always hermaphrodite, this coral is rarely so, but the polypes of different branches belong to different sexes.

As in the other polypes, including Actinia, the eggs and spermatic particles rupture the walls of their respective glands situated in the fleshy partitions. As in Actinia, Lacaze-Duthiers thinks the fecundation of the egg occurs before it leaves the ovary, when also the segmentation of the yolk must take place. Unlike the embryo Actinia, the ciliated young of the coral, after remaining in the digestive cavity for three or four weeks, make their way out into the world through the tentacles. "Many times," says Lacaze-Duthiers "have I seen the end of the tentacle break and let out the embryo." The appearance of the embryo, when first observed, was like that in Fig. 77, A, an oval, ciliated body with a small mouth and a digestive cavity. This may be called the gastrula, adopting Hæckel's phraseology.

Fig. 76.

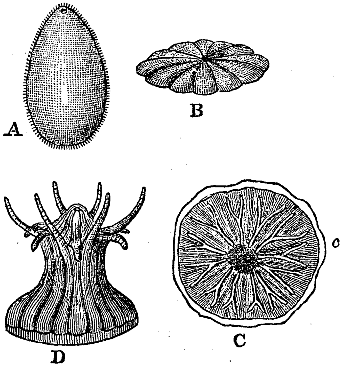


Coral polype (Astræoides calycularis) expanded.

The gastrula changes into an actinoid polype in from thirty to forty days in confinement, after exclusion from the parent, but in nature in a less time, and it probably does not usually leave the mother until ready to fix itself to the bottom.

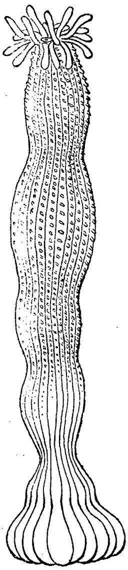
Before the embryo becomes fixed and the tentacles arise, the lime destined to form the partitions begins to be deposited in the endoderm. Fig. 77, C, shows the twelve rudimentary septa. These after the young actinia, or "actinula" (Allman), has become stationary, finally enlarge and become joined to the external walls of the coral now in course of formation (Fig. 77 C, *c*) forming a groundwork or pedestal on which the actinula rests. D represents the young polype resting on the limestone pedestal.

Fig. 77.



Development of a coral polype, Astræoides calycularis. After L. Duthiers.

Fig. 78.



Halcampa albida.

In the experience of Lacaze-Duthiers it happened that the embryo polype which had been swimming about in his jars for about a month, suddenly, within the space of three or four hours after a hot sirocco had been blowing for three days, assumed the form of small disks (Fig. 77, B), divided as in the Actinia into twelve small folds forming the bases of the partitions within.

The tentacles next arise, being the elongation of the chambers between the partitions, six larger and elevated, six smaller and depressed (Fig. 77, D). The definitive form of the coral polype is now assumed, and in the Astræoides it becomes a compound polypary.

The singular floating young Edwardsia, originally described under the name *Arachnactis*, has been found by Mr. A. Agassiz to be the early swimming stage of Edwardsia, a worm-like Actinian, which, like *Halcampa albida* (Fig. 78[1]), lives in the sand or mud, unattached to any fixed object.

Kowalevsky has lately found that the Cerianthus, a gigantic Actinia which lives in a tube in the mud at great depths, has a free swimming early stage like Edwardsia.

The following is a summary of the changes undergone by the polypes so far as known :—

1. Egg fertilized by true spermatozoa.

2 ? Morula.

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[1] This figure was kindly loaned by Professor S. F. Baird, U. S. Commissioner of Fish and Fisheries.

3. Planula (Gastrula).
4. Actinula, with twelve primitive tentacles.
5. Adult actinia or polype.

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IV. THE CTENOPHORÆ.

These beautiful animals derive their name Ctenophoræ, or "comb-bearers," from the vertical rows of comb-like paddles, situated on horizontal bands of muscles, which serve as locomotive organs, the body not contracting and dilating as in the true jelly fishes. In their organization they are much more complicated than any animals of which we have yet spoken, as it has been shown by the two Agassizs that they have a true digestive cavity, passing through the body cavity, with a posterior outlet, and originating in the same manner as in the Echinoderms. From this alimentary canal are sent off chymiferous tubes which "correspond in every respect with the water tubes of the Echinoderms" (A. Agassiz). The rows of paddles are intimately connected with the chymiferous tubes, so that the movements of the body are in direct relation with the act of breathing. Moreover these animals, while in the disposition of the organs following the radiate plan of structure, are also more truly bilateral than any of the lower classes of radiates. The sexes are united in the same individual; the ovaries in Idyia are on one side of the main chymiferous tube, and the spermaries on the other, both being brilliantly colored.

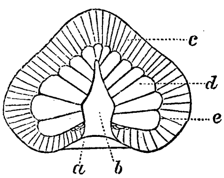
Referring the reader for farther details to Mr. A. Agassiz's "Sea Side Studies," where these animals are described and illustrated with sufficient detail for the general reader, we will now turn to their mode of growth, under the guidance of the same author, whose recent richly illustrated memoir, with others by Kowalevsky and Fol leaves but few gaps to be filled by future observers.

Development. Agassiz states that the Ctenophoræ are readily kept in confinement, and from twelve to twenty-four hours after they are captured lay their eggs, either singly or in strings, or, as in Idyia, in a thick slimy mass. The Ctenophoræ of our eastern coast spawn from late in July through August and September. "The young brood developed during the fall, comes to the surface again the following spring as nearly full-grown Ctenophoræ, to lay their eggs late in the summer." Fortunately the eggs are so transparent that in some forms (Pleurobrachia and Bolina) the embryology can be studied, not only in the egg but also through nearly all the earlier stages of the larva.

Selecting Pleurobrachia as an example of the mode of growth, we find that as in Idyia the egg consists of two layers, *i. e.* an inner yolk mass and an outer, thin, finely granular layer surrounded by a transparent envelope. The inner mass acts merely as a nutritive mass, while the outer is the true embryonic layer, which builds up the body at the expense of the central nutritive mass. No nucleus nor nucleolus has been observed by Agassiz in the eggs of any Ctenophoræ, after they are once laid, until late in the stage of segmentation. The egg divides into four and again eight spheres of segmentation, each of which has, like the egg, originally an outer and inner mass. In a second stage of segmentation small cells arise which surround the original eight large cells. From these small cells the external organs are destined to arise, while the larger cells form a yolk mass out of which the internal organs arise.

The embryonal layer is next formed, then the outer wall by "the gradual encroachment of the actinal cells over the whole of the yolk mass." Finally, the mouth (actinostome) of the germ is formed, and afterwards the digestive cavity, which results from an invagination of the outer embryonic layer (ectoderm). Fig. 79 (after Metschnikoff) represents the larva of a Cydippe; *a*, primitive opening; *b*, gastrovascular cavity; *c*, ectoderm; *d*, endoderm; *e*, interspace corresponding to the body cavity of the larva of the polype. The development of the chymiferous tubes is succeeded by that of the locomotive flappers, eight or nine pairs in each row appearing before the young leave the egg, and of the fringed tentacle, which attains a great length after the young is hatched.

Fig. 79.

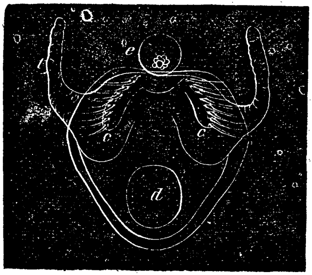


Gastrula of Cydippe.

Finally the definitive form of the Pleurobrachia is attained before it leaves the egg, as seen in Fig. 80 (*t*, tentacles; *e*, eyespeck; *c*, *c*, rows of locomotive flappers; *d*, digestive cavity; greatly magnified after A. Agassiz).

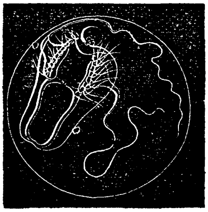
Fig. 81 shows the young Pleurobrachia swimming about in the egg just before hatching, and in Fig. 82 (after A. Agassiz), we see the young after hatching (magnified) with nearly the same form as the adult; *f* indicates the funnel leading to the anal opening, *l*, the lateral tubes, and *c c c′ c′* the rows of locomotive flappers. The remaining changes are slight, and there is not even a slight metamorphosis, the body simply becoming spherical and the tentacles increasing enormously in length. In Bolina and its allies, as A. Agassiz states, "the morphological changes are very great, and it would indeed puzzle the most accurate systematist to recognize in the early stages of some of the Mnemidæ the young of well known genera. We cannot say that there is a metamorphosis in the ordinary sense of the word, as supposed by Gegenbaur, but there certainly are remarkable changes, such as the almost total suppression of the tentacular apparatus, the development of auricles, of lobes, with their complicated winding chymiferous tubes, which alter radically the appearance of the Ctenophoræ at successive periods of growth, and present between the younger and the older stages differences usually considered as of great systematic value."

Fig. 80.



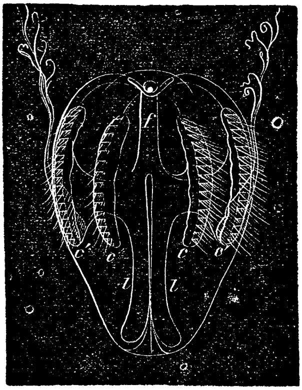
Young Pleurobrachia still in the Egg.

Fig. 81.



Young Pleurobrachia swimming in egg ready to hatch.

Fig. 82.



The same after hatching.

The summary of stages is very brief, the Ctenophore passing through three phases:—

1. Egg stage.
2. Morula state.
3. Adult form, assumed before hatching.

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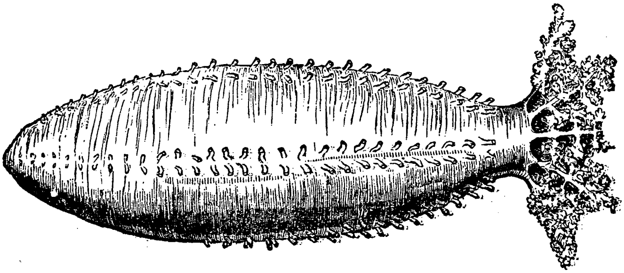
V. THE ECHINODERMS.

The Echinoderms (starfishes, sea urchins and sea cucumbers) are far more complicated than the Cœlenterates, having a true alimentary canal passing through the general cavity of the body. In them for the first time among the Radiates appears a well developed nervous system. Not only do the young exhibit a bilateral symmetry, but in the higher forms, as the spantangoid sea urchins, this is quite well marked; and there is a dorsal and ventral side. Still, in the generality of the forms, the radiated plan of structure is remarkably adhered to, the body as distinctly made up of sphæromeres, or wedge-shaped sections of the body, as the worms are of segments (arthromeres). In this and other respects, as well as the form of the larvæ, there is a remarkable parallelism between the worms and echinoderms.

Fig. 83.

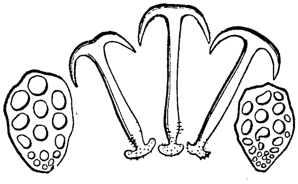


Pendacta frondosa (From Tenney's Zoology.)

We will briefly review some of the anatomical features of the Echinoderms, in order to understand their complicated mode of growth.

The stomach and intestinal canal either pass straight or in a spiral course through the body, as in the sea urchins (Fig 103) and Holothurians (Fig. 83), and open out at the opposite end; or, as in the Antedon (Comatula), the anal opening is situated near the mouth, while in the Ophiurans (Fig. 85) and Luidia and Astropecten, low starfishes, the undigested food is rejected from the mouth. In the starfishes and Holothurians, the alimentary canal opens into five voluminous cæcal appendages. These are wanting in the Ophiurans, and there are but two in Astropecten. They are in connection with the complicated water tubes, which consist of a canal surrounding the mouth and sending branches out into the rays of the starfishes in communication with the locomotive organs or suckers, called ambulacra. The water fills the tubes through a duct leading from the sieve-like plate, situated in the dorsal (abactinal) portion of the body. Near this duct is the pulsating tube, the so-called heart.

Fig. 84.

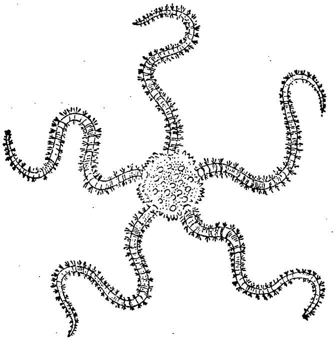


Hooks and Plates of Synapta.

The Echinoderms are further distinguished by the body walls secreting calcareous plates, often forming a solid limestone shell, as in the sea urchins; or the plates are smaller and movable as in the starfishes, or as in the sea cucumbers they are microscopic, buried in the skin; sometimes, as in the Synapta forming anchor-like hooks and small plates (Fig. 84).

The sexes are as a rule distinct. In *Ophiura squamata* and Synapta they are united in the same individual. The ovaries and testes are gland-like masses situated at the base of the arms in the starfishes, or between the ambulacra in the sea urchins. The ovaries are red or yellow, the male glands

Fig. 85.



Sand star (Ophiopholis aculeata).

whitish. In the Ophiurans the eggs and spermatozoa pass out of the body through little holes between the plates on the under side of the body. In those starfishes in which the alimentary canal is a blind sac, the eggs are emptied into the body cavity; but how they pass out is unknown. In some starfishes they escape through certain (interradial) plates on the back. In the Echinoids they make their exit from between the ambulacra. In the Holothurians, however, there is a duct leading from the generative gland opening out near the mouth, between the tentacles. The eggs are usually round, and minute; the spermatozoa of the usual tailed form. Fertilization takes place in the water.

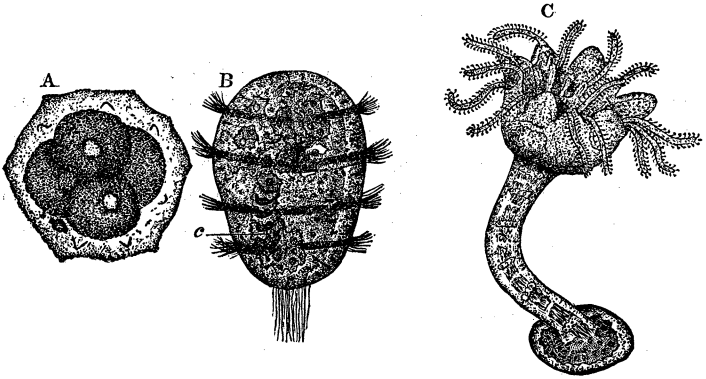
Remembering that there are five well-marked divisions of Echinoderms, *i.e.*, *Crinoidea*, *Ophiuroidea*, *Asteroidea*, *Echinoidea*, and *Holothuroidea*, we will now review some of the main points in the mode of development of the respective orders.

Development of the Crinoids. While we know nothing of the mode of development of the true Pentacrinus and Rhizocrinus, the lineal descendants of the Crinoids of the earlier geological ages, we have quite full information regarding the life-history of the Antedon, which is for a part of its life stalked, and is in fact a true crinoid.

The following account is taken (sometimes word for word) from Professor Wyville Thompson's researches on the *Antedon rosaceus* of the British coast. The ovaries open externally on the pinnules of the arms, while there is no special opening for the spermatic particles, and Prof. Thompson thinks they are "discharged by the thinning away and dehiscence of the integument." The ripe eggs hang for three or four days from the opening like a bunch of grapes, and it is during this period that they are impregnated. The egg then undergoes total segmentation. Fig. 86, A, represents the egg with four nucleated cells, an early phase of the mulberry or morula stage. After the segmentation of the yolk is finished, the cells become fused together into a mass of indifferent protoplasm, with no trace of organization, but with a few fat cells in the centre. This protoplasmic layer becomes converted into an oval embryo, whose surface is uniformly ciliated. The mouth is formed, with the large cilia around it, before the embryo leaves the egg. When hatched, the larva is long, oval, and girded with four zones of cilia, with a tuft of cilia at the end, a mouth and anal opening, and is about ·8 millimetre in length. The body cavity is formed by an inversion of the primitive sarcode layer which seems to correspond to the ectoderm.

Within a few hours or sometimes days, there are indications of the calcareous areolated plates forming the cup of the future crinoid. Soon others appear forming a sort of trellis work of plates and gradually build up the stalk, and lastly appears the cribriform basal plate. Fig. 86, B, *c*, represents the young crinoid in the middle of the larva, whose body is somewhat compressed under the covering glass. Next appears a hollow sheath of parallel calcareous rods, bound, as it were, in the centre by the calcareous plates. This stalk (B, *c*) arises on one side of the digestive cavity of the larva, and there is no connection between the body cavity of the larva and that of the embryo crinoid.

Fig. 86.



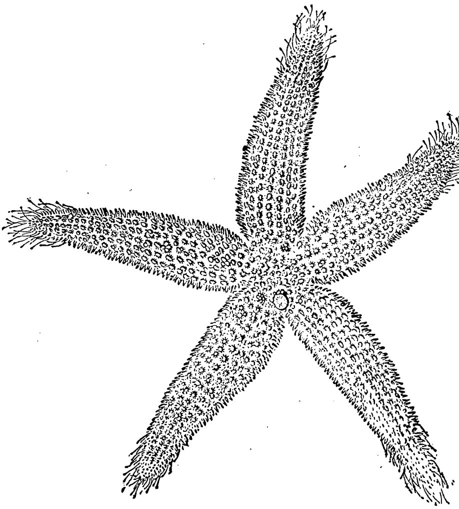
Development of a Crinoid (Antedon).

Two or three days after the appearance of the plates of the crinoid, the larva begins to change its form. The mouth and digestive cavity disappear, not being converted into those of the crinoid. The larva sinks to the bottom resting on a seaweed or stone to which it finally adheres. The Pentacrinus is embedded in the former larval body (the cilia having disappeared), now constituting a layer of sarcode conforming to the outline of the Antedon.

Meanwhile the cup of the crinoid has been forming. It then assumes the shape of an open bell; the mouth is formed, and five lobes arise from the edges of the calyx. Afterwards five or more, usually fifteen tentacles, grow out, and the young Antedon appears as in Fig. 86, C (after Thompson). The walls of the stomach then separate from the body-wall. The animal now represents the primary stage of the crinoids, that which is the permanent stage in the Pentacrinus and its fossil allies. The Antedon, however, in after life separates from the stalk and moves about freely.

Development of the Starfish. We will select as a type of the mode of development of the starfishes, that of the common five finger, Asterias (Fig. 87), as worked out with great thoroughness by Mr. A. Agassiz, and given in the "Seaside Studies." The accompanying illustrations are taken from this work and the original memoir, through the kindness of the author, whose description is here freely used.

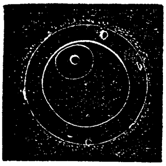
Fig. 87.



Asterias.

Fig. 88 shows the transparent spherical egg, enclosing the germinative vesicle and dot, and Figs. 89, 90, illustrate the segmentation of the yolk into two and eight and more cells, enclosing a central cavity. After this the embryo hatches and swims about as a transparent sphere (Fig. 91). A depression (Fig. 92, *ma*) then begins to appear, the body elongates, and this depression forms an inversion of the outer wall of the body (ectoderm), constituting the body cavity (*d*, Fig. 93, *a*), being the provisional mouth-opening, afterwards becoming the anal opening; at this time, however, serving both for taking in and rejecting the food). From the upper extremity of the digestive cavity next project two lobes (*w*, *w′*, Fig. 94, *m*, mouth). These separate from their attachment and form two distinct hollow cavities (*w*, *w′*, Fig. 95, *a*, *d*, *c*, digestive system; *v*, vibratile chord; *m*, mouth). Here begins the true history of the young starfish, for these two cavities will develop into two water-tubes, on one of which the back of the starfish, that is, its upper surface, covered with spines, will be developed, while on the other, the lower surface, with the suckers and tentacles, will arise. At a very early stage one of these water tubes (*w′* Fig. 96) connects with a smaller tube opening outwards, which is hereafter to be the madreporic body (*b*, Fig. 96). Almost until the end of its growth, these two surfaces, as we shall see, remain separate and form an open angle with one another; it is only toward the end of their development that they unite, enclosing between them the internal organs, which have been built up in the meanwhile.

Fig. 88.



Egg of Starfish.

Fig. 89.

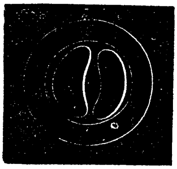
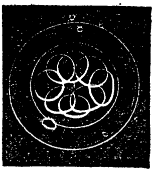
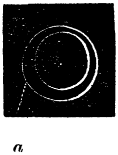


Fig. 90.



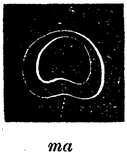
Segmentation of yolk.

Fig. 91.



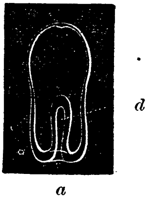
Free swimming germ.

Fig. 92.



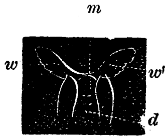
The same, older.

Fig. 93.



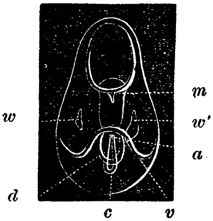
Gastrula.

Fig. 94.



Mouth of Gastrula.

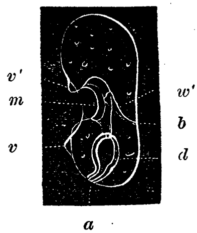
Fig. 95.



Larva.

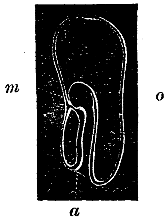
"At about the same time with the development of these two pouches, so important in the animal's future history, the digestive cavity becomes slightly curved, bending its upper end sideways till it meets the outer wall, and forms a junction with it (*m*, Fig. 97; *o*, digestive cavity). At this point, where the juncture takes place, an aperture is presently formed, which is the true mouth. The digestive sac, which has thus far served as the only internal cavity, now contracts at certain distances, and forms three distinct, though connected cavities as in Fig. 96, viz., the œsophagus leading directly from the mouth (*m*) to the second cavity or stomach (*d*), which opens in its turn into the third cavity, the alimentary canal. Meanwhile the water-tubes have been elongating till they now surround the digestive cavity, extending on the other side of it beyond the mouth, where they unite, thus forming a Y-shaped tube, narrowing at one extremity, and dividing into two branches toward the other end, Fig. 98.[2]

Fig. 96.



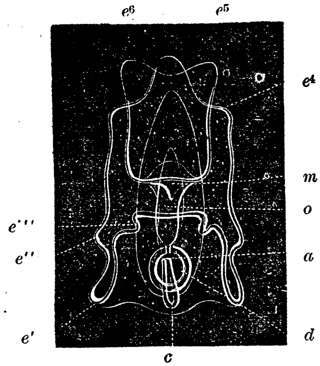
Profile view of Larva.

Fig. 97.



Larva.

Fig. 98.



Larva with arms developing.

"On the surface where the mouth is formed, and very near it on either side, two small ones arise, as *v* in Fig. 95; these are cords consisting entirely of vibratile cilia. They are the locomotive organs of the young embryo, and they gradually extend until they respectively enclose nearly the whole of the upper and lower half of the body, forming two large shields or plastrons (Figs. 98, 99). The corners of these shields project, slightly at first (Fig. 98), but elongating more and more until a number of arms are formed, stretching in various directions (Figs. 99, 100)[3] and, by their constant upward and downward play, moving the embryo about in the water" (A. Agassiz).

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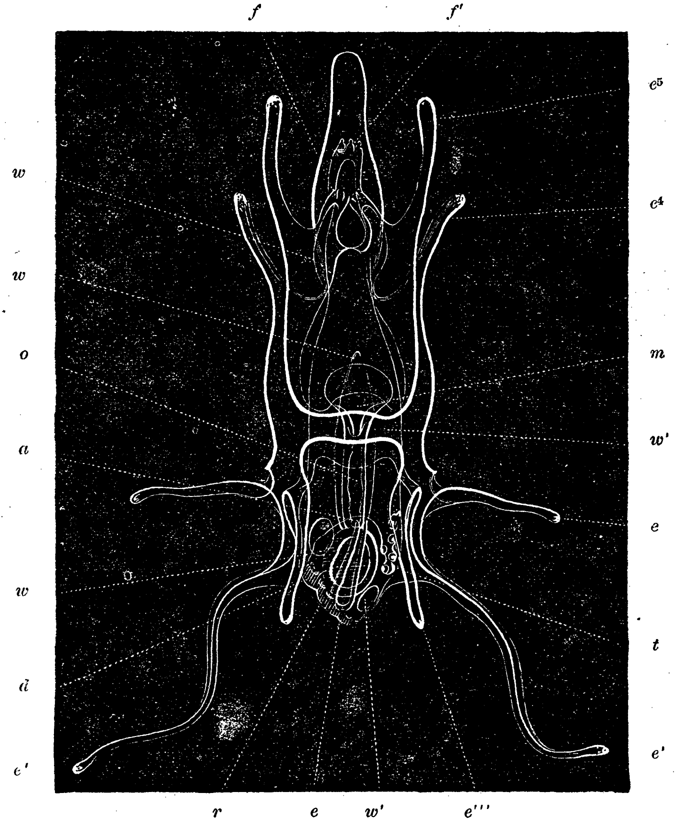
[2] Fig. 98, *a*, anus; *c*, intestine; e' e'' e''' e^4 e^5 e^6, arms; *o*, œsophagus.

[3] Figs. 99, 100, side view of 99. Adult larva, so-called Brachiolaria, lettering the same in all the figures; *t*, tentacles of young starfish; *ff*, brachiolar appendages; *r*, back of young starfish. Fig. 101, *t'*, odd tentacle.

Having reached the Brachiolaria stage, the body of the future starfish begins to develop. On one of the water-tubes (*w'*) the tentacles of the future starfish arise as a series of lobes (*t*); while on the opposite water-tube (*w*), arise a number of little calcareous rods, which afterwards form a continuous net-work; *r* indicates the back of the young starfish. The larva now shrinks and drops to the bottom and attaches itself there by means of the short arms (*ff'* Fig. 99). The starfish now absorbs the larva, and

Fig. 99.



Full grown larva of Starfish, or Brachiolaria.

appears of an oval form with a crenulated edge, and soon reaches a stage indicated by Fig. 101. (Fig. 102, the same seen in profile).

In this stage it remains probably two or three years before the arms lengthen and the adult form is assumed.

Fig. 100.

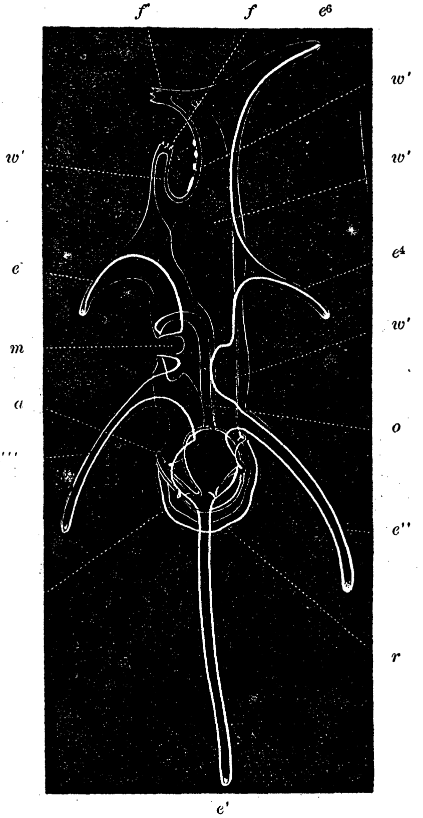
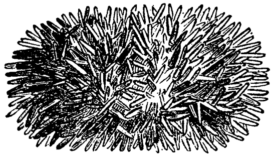


Fig. 99 seen in profile.

The development of the Ophiurans is much like that of the starfish, with some characters of the embryo sea urchin. The larva of the sand star (Ophiura) is called a Pluteus, and is remarkable for the great length of two of the arms.

Development of the Echinoids. The researches of Mr. A. Agassiz, who has given us a very complete history of the common sea urchin of the northern shores of the United States in his "Revision of the Echini," will be our guide in these studies. The earlier stages of development were obtained by artificial fecundation of the egg during February. The early embryonic stages are much as described in the starfishes, the process requiring but a few hours. The embryo when hatched is like that of the starfish at the same period (Fig. 91) and then it passes into the gastrula stage (Fig. 104, lettering the same in all the figures as in those of the starfish) the digestive cavity being formed by an inversion of the ectoderm. "The embryo, in escaping from the egg, resembles a starfish embryo, and it would greatly puzzle any one to perceive any difference between them. The formation of the stomach, of the œsophagus, of the intestine, and of the water tubes takes place in exactly the same manner as in the starfish, the time only at which these different organs are differentiated not being the same. In figure 105 we see the beginning at *w* and *w'* of the water tubes arising as pouches sent off from the digestive cavity, and T-shaped rudiments of the limestone rods (*r*), so characteristic of the larva of the sea urchin are now visible.”

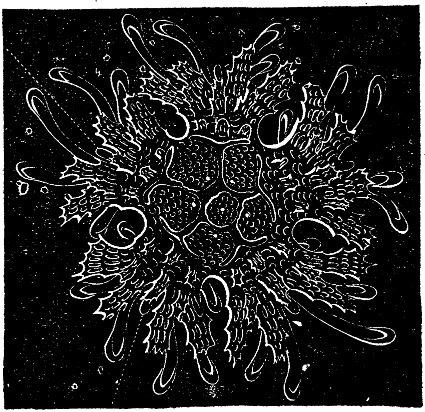
Fig. 103.



Common Sea Urchin (Echinus).

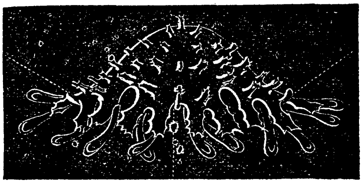
Fig. 106 represents the larva well advanced towards the pluteus stage. It is now in the tenth day after fecundation.[4] The arms are now well marked, and the “vibratile epaulettes” appear. When the larva is twenty-three days old, the rudiments of the five tentacles of the sea urchin appear, the first one on the left water tube. The arms have increased in length, until in the full-grown larva, now called the pluteus (Figs. 107, 108, the same seen sidewise) the arms with the calcareous rods supporting them are of great length, opening and shutting like the rods of an umbrella; while the sea urchin growing within has concealed the shape of the digestive cavity of the larva, and the spines are so large as to conceal the tentacles.

Fig. 101.



Young Starfish seen from the back.

Fig. 102.



Young Starfish seen in profile.

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[4] Fig. 106, e–e^{iv} arms; v-v', vibratile chord, w w', earlets, water tubes; *a o d c*, digestive system; r–r''' solid rods of the arms; *m*, mouth; *b*, madreporic opening. Fig. 107, *f*, brachilar appendages.

The pluteus, a nomadic stage of the echinus, is as Mr. A. Agassiz states "a scaffolding in which the future sea urchin plays but a secondary part, and is composed of two open spirals, the one to form eventually the complicated abactinal system (the interambulacral and ambulacral plates), the other to form the water system, and holding between them the digestive cavity and other organs of the pluteus, which as yet appear to have no connection whatever with the spines of the future Echinus. Yet towards the end of the nomadic pluteus life a few hours are sufficient to resorb the whole of the complicated scaffolding, which has been the most striking feature of the Echinoderm, and it passes into something which, it is true, we could hardly recognize as an Echinus, yet has apparently nothing in common with its former condition."

Fig. 104.

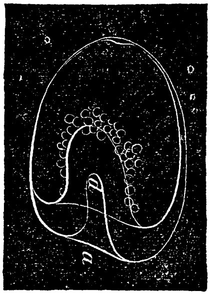


Fig. 105.

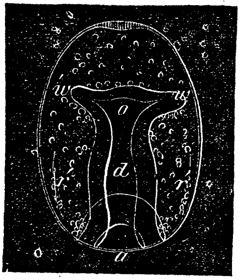
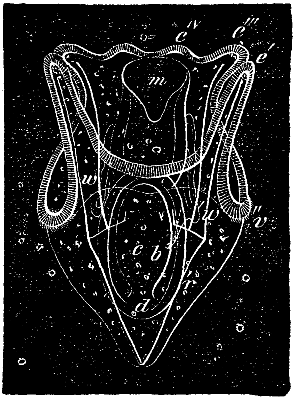


Fig. 106.



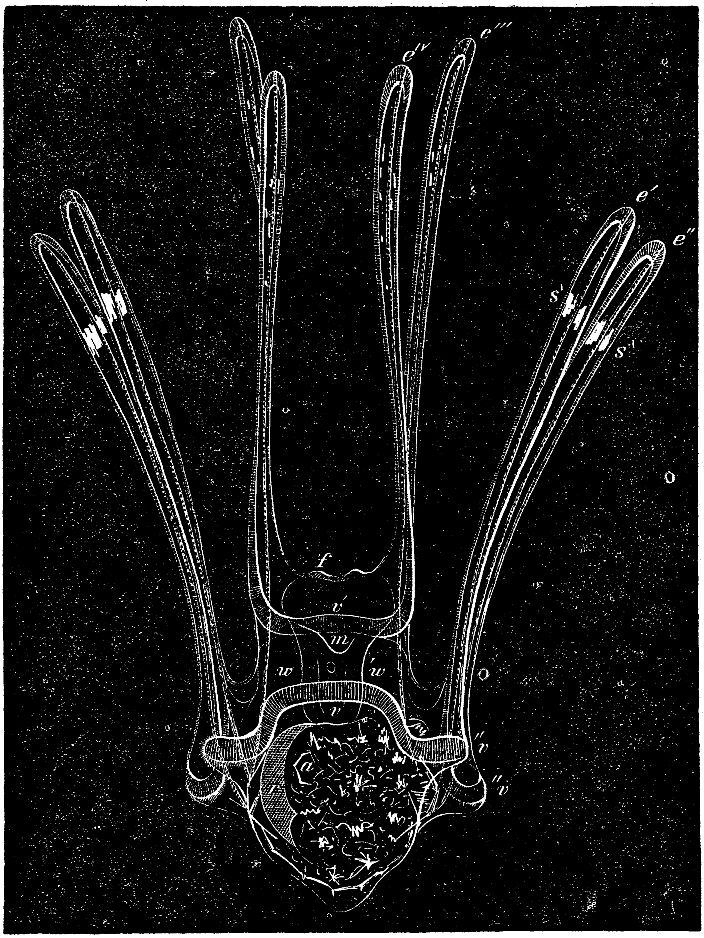
Development of the Pluteus of the Sea Urchin.

From this time the body of the pluteus is absorbed by the growing sea-urchin; the spines and suckers of the latter increasing in size and number with age, and by the time the larval body has disappeared the young Echinus is more like the adult than the starfish at the same period in life. Fig. 109 (*tt*, tentacles; *s''s'''*, spines) represents the sea urchin very soon after the resorption of the pluteus.

In after life the young sea urchin with its few and large spines resembles Cidaris and a number of allied forms, showing that these genera, which appeared earlier geologically than our common Echinus (Fig. 103, *Strongylocentrotus Dröbachiensis*), are lower in development.

Development of the Holothuroids. Of the development of our native sea cucumbers our knowledge is exceedingly fragmentary, and for nearly all that we do know of the mode of growth of these animals in general, we are indebted to the elabo-

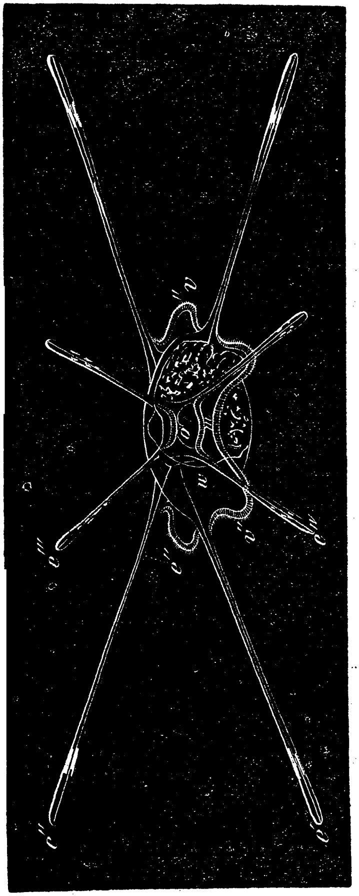
Fig. 107.



Pluteus of the Sea Urchin.

rate researches of the distinguished J. Müller. He figures the earliest stage of the larval Holothurian, which he calls an "Auricularia." The course of development is much as in the starfishes. The earliest stage known resembles that of the starfish represented by Fig. 93. It then passes through a stage represented by Fig. 96, when the mouth and digestive tract is formed, and again a stage analogous with Fig. 98. The Auricularia when fully grown, is cylindrical, annulated, with four or five bands of cilia, usually with ear-like projections, whence its name Auricularia. Before it becomes fully formed the young Holothurian begins to grow near the side of the larval stomach, the calcareous crosses appear and the tentacles of the future Holothurian bud out. The ear-like projections disappear, the Auricularia becomes cylindrical, and is now called the "pupa." The Auricularia is gradually absorbed and the young Holothurian strikingly resembles a worm. In this pupa stage, in certain transparent forms observed by Müller, the intestine of the embryo Holothurian could be observed twisted on itself, with the mouth surrounded by tentacles. The only observations published on our native Holothurians are those of Mr. A. Agassiz, on Cuvieria, our large red, heavily plated sea-cucumber, which inhabits stony bottoms in deep water. The young are of a brilliant vermilion. In the earliest stage observed by Mr. Agassiz (Fig. 110 *l*, "pupa;" *g*, tentacles);

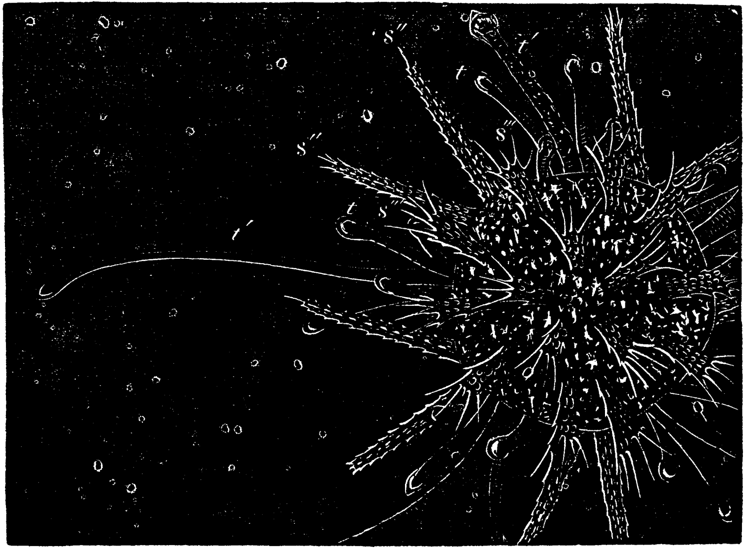
Fig. 108.



Profile view of 107.

the "pupa" or second form of the Auricularia is very large and the tentacles do not project beyond the body, as they afterwards do (Fig. 111) when the Auricularia is nearly absorbed by the growing Holothurian. In a succeeding stage the tentacles begin to branch, where before they were simple and knobbed. At this time the œsophagus, stomach, intestine and anus are developed, and there is a ring of limestone rods and crosses around the mouth. The madreporic body (*b*) has not yet been drawn within the body.

Fig. 109.



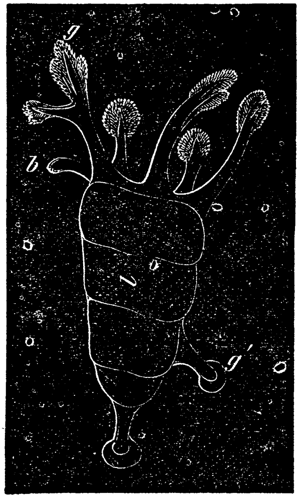
The young Echinus.

Finally, the Auricularia becomes wholly absorbed, the tentacles are much branched and capable of retraction within the body; the tegument secretes limestone plates, the suckers are developed in the ambulacral rows and the adult form is attained without important changes. Fig. 83 represents a common sea-cucumber of our coast.

Some holothurians, as well as starfishes and ophiurans, as observed by Mr. A. Agassiz, undergo their larval (*i. e.*, Pluteus, Brachiolaria and Auricularia) phases of development above described without leaving the parent, in pouches held over the mouth of the parent, making their escape in a form approaching that of the adult.

Metschnikoff has made some valuable comparisons between the ciliated embryos of the Cœlenterates and Echinoderms, and shows that the primitive body-cavity of the former is not homologous with the peritoneal cavity (*i. e.*, the space in which the digestive canal hangs) of the Echinoderms. He also shows that while the primitive body cavity of the Cœlenterates remains permanently as the digestive tract; in the Echinoderms it is temporary and embryonic. Metschnikoff, on embryological grounds (a view which the structure of the adult animals confirms), thinks that there is the same similarity between the Cœlenterates (Acalephs and Ctenophoræ) and Echinoderms, as between the higher worms (Hirudineæ, Gephyrea and Annelides), and the Crustacea and Insects.

Fig. 112.



Larva of Cuvieria.

Reproduction by fission as in the Actiniæ and jelly fishes very rarely occurs in the Echinoderms. An Ophiuran deprived of all its arms will reproduce them by budding, and Lütken shows that certain starfishes divide in two spontaneously, having three arms

Fig. 110.

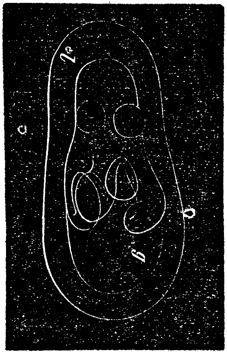
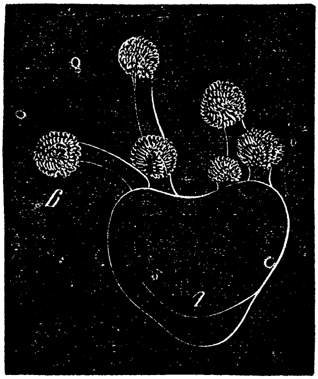


Fig. 111.



Development of a Holothurian (Cuvieria).

on one side and three on the other, while the disk looks as if it had been cut in two by a knife, and three new arms had then grown out from the cut side.

Echinoderms as a rule, then, are reproduced alone by eggs and sperm cells. After fertilization of the egg they pass through:

1. Morula stage.
2. Gastrula stage.
3. A larval, temporary stage (Pluteus, Brachiolaria, Auricularia).
4. The Echinoderm grows from a water tube of the larva, finally absorbing the latter, whose form is often materially changed during the process. It thus undergoes a true metamorphosis, in a degree comparable with that of some insects.

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REVIEWS AND BOOK NOTICES.

The Geological Survey of Missouri.—We have too long delayed our notice of the two octavo volumes from the geological survey of Missouri, which, though bearing the date of 1873, were not distributed till 1874. The first of these is a collection of reports from 1855 to 1871, by Messrs. Brodhead, Meek & Shumard, and the second, the results of the work of 1872, is devoted to the iron and coal deposits of the state. Of these the former are described by Dr. Adolph Schmidt, and the latter by Mr. Brodhead; in addition to which the late director, Prof. Raphael Pumpelly, has prefixed an important chapter on the geology of the Pilot Knob district, and its iron ores, from which, and from the copious descriptions of Dr. Schmidt, we gather a pretty complete account of this extremely curious region. Rising above the floor of horizontal palæozoic deposits, the 3d Magnesian limestone of Swallow, a member of a group of strata supposed to correspond to the Potsdam of New York, appear numerous hills of crystalline rock, described as exposed portions of the skeleton of the eastern part of